BONNEVILLE POWER ADMINISTRATION

Pacific Ocean Shelf Tracking Project (POST)

Results from the Acoustic Tracking Study on Survival of Columbia River Salmon

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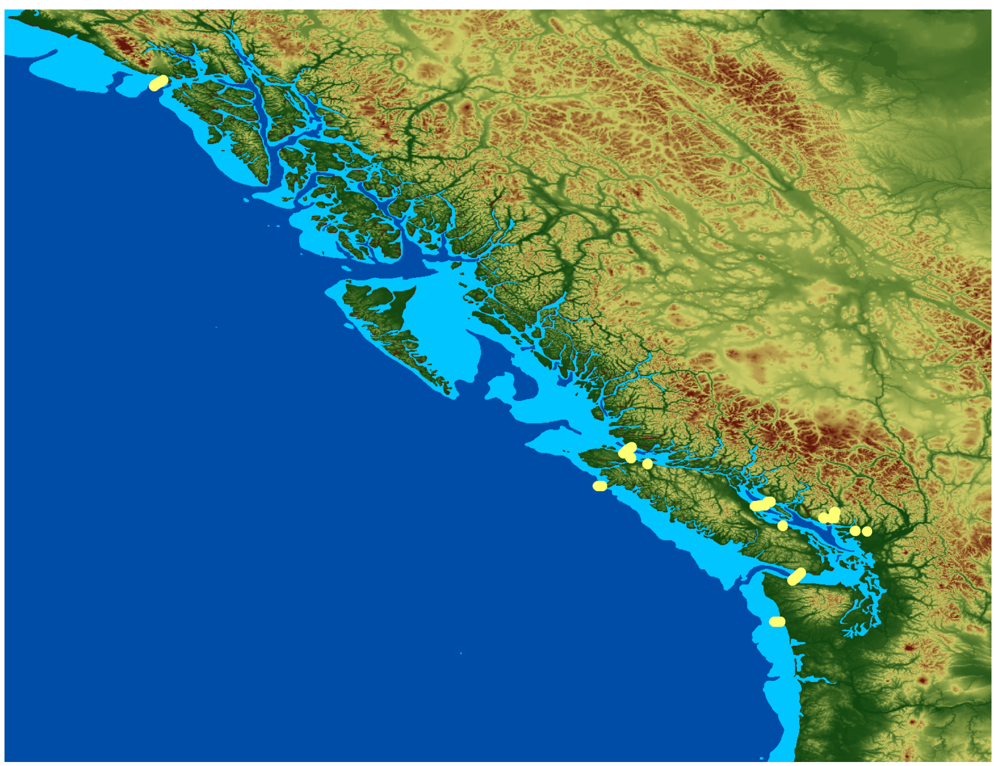
Pacific Ocean Shelf Tracking Project (POST): Results from the Acoustic Tracking Study on Survival of Columbia River Salmon

Annual Report to the Bonneville Power Administration

Contract No. 2003-114-00, Grant No. 00021107

December 6, 2005

Location of the POST acoustic tracking array in 2005. Bathymetric and topographic data courtesy of the Government of Canada and NOAA



EXECUTIVE SUMMARY

On May 22, 2005, 198 acoustically tagged Chinook smolts were released into the Columbia River 4 km downriver of Bonneville Dam. A total of nineteen of these smolts were subsequently detected on three acoustic listening lines placed partway across the continental shelf near Cape Elizabeth, Washington, and Brooks Peninsula, northwest Vancouver Island, and across the Strait of Juan de Fuca. One additional fish may have been detected off the mouth of the Keogh River, northeast Vancouver Island, although the validity of this detection is not certain. With the exception of the fish heard on the Juan de Fuca line, the Chinook smolts were travelling quickly, at average rates near 1.5 to 2 body lengths per second, or 20-25 km/d in the ocean (depending on what rate of travel is assumed for initial migration down the Columbia River). Even at the lower end of this range of swimming speeds, most smolts are expected to arrive at an additional listening line in southeast Alaska within the projected transmission life span of the acoustic tags; this will be verified when this line is recovered in December or January (recovery in the winter is strongly weather dependent). In addition to the Snake River smolts, the acoustic lines recorded the passing of large numbers of POST and non-POST acoustic tags, including green sturgeon tagged in Oregon & California.

Problems were encountered with equipment recovery on both the Cape Elizabeth and Brooks Peninsula lines, mainly as a result of poor performance of the acoustic releases; the cause of these failures is known, and the problems will be rectified in time for the 2006 field season. Recovery was further complicated by the difficult environment at both these sites, including factors such as wave action, sand movement, and strong currents. As a result, the overall detection efficiency of both lines was reduced because of the partial recovery of acoustic tracking receivers containing the recorded tracking data. Despite these issues, almost all receivers responded to attempts at acoustic communication, confirming that most of the equipment had remained in place and continued to function normally. On those inner lines within the Strait of Georgia where complete recovery of multiple acoustic listening lines was achieved, performance of the individual listening lines in 2004 and 2005 increased from 91% of smolts detected to 95.5%. This difference represents a doubling in detection efficiency from missing one in 11 passing smolts in 2004 to missing one in 20 passing smolts in 2005.

The distribution of tagged fish (including Snake River chinook) that were detected near the outer end of the Cape Elizabeth and Brooks Peninsula listening lines suggest that the lines should be extended to the shelf break if all migrating Snake River smolts are to be recorded. In contrast, the Juan de Fuca line performed very well, and was able to follow the movements of a single Snake River chinook smolt in detail as it crossed the line on two separate occasions. Based on the results from the 2005 field season, a nearly complete census of migrating salmon smolts is feasible, thus allowing the direct measurement of movement and survival of Columbia and Snake River chinook in the ocean. The 2004 and 2005 results clearly indicate the northward migrating smolts originally tagged in the Columbia River migrate rapidly up the shelf. They do not enter the Strait of Georgia via Juan de Fuca on their way north, but instead migrate up the west coast of Vancouver Island.

2005 FIELD SEASON

Acoustic tags were surgically implanted into the abdominal cavities of 200 Chinook smolts at the Kooksia Hatchery in Idaho on May 11-12, 2005, following Kintama Research Corporation's standard surgical procedures (described in Appendix A3). Smolts ranged in size from 140-167 mm, with a mean fork length of 149 mm. Surgeries took place without complications or mortalities. However, two fish died when they jumped through a gap in the lid of the post-operative holding tank.

On May 20, the tagged smolts were transferred via dip net into an oxygenated 300L tank and driven by road the 123 miles from the Kooskia Hatchery to Lower Granite Dam. The transport tank was supplied with two recirculation pumps and two air stones connected to an oxygen tank. The smolts were transferred to an Army Corps of Engineers barge and transported from the Lower Granite Dam to the release site 4 km down-river from the Bonneville Dam, at river mile 139 (Figure 1). Release of the smolts went smoothly, and no mortalities were observed at any point during the transport process.

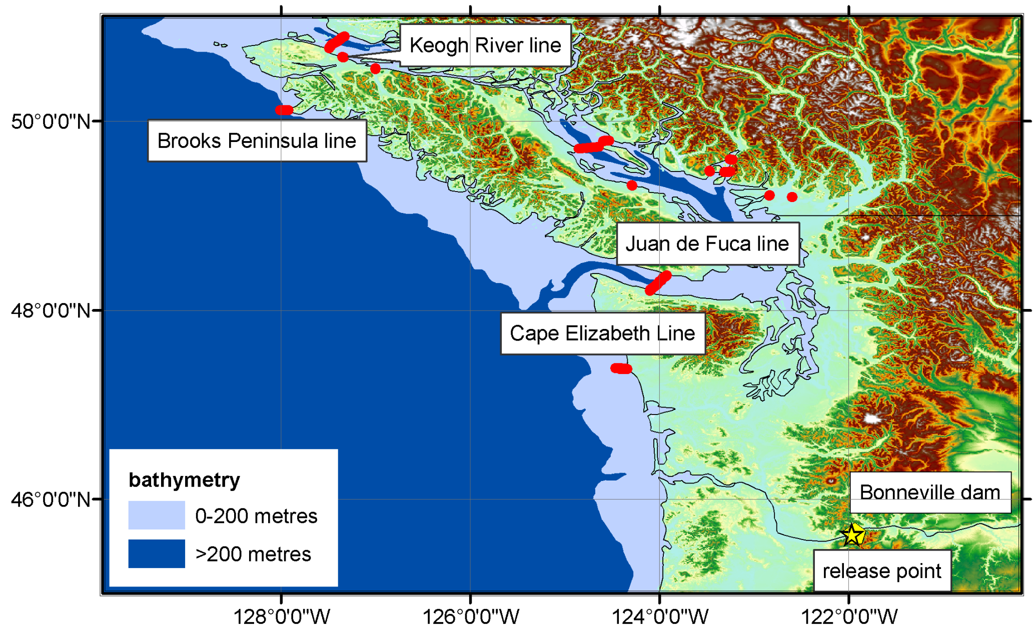


Figure 1. Region of interest for the tracking of acoustically tagged Snake River Chinook during the summer of 2005. Tagged smolts were released into the Columbia River approximately 4 km down-river from the Bonneville Dam, and were recorded as they travelled past the Cape Elizabeth, Juan de Fuca, and Brooks Peninsula lines of acoustic receivers. The Alaska line, situated across the shelf north of the Alaska panhandle, is not shown in this figure, but lies 1,550 kms north of the Cape Elisabeth line. Bathymetric and topographic data courtesy of the Government of Canada and NOAA, respectively[1].

Northward migration of the tagged smolts was recorded on the Pacific Ocean Shelf Tracking (POST) acoustic listening array. The 2005 POST array, now in the second year of its test phase, consisted of a total of 135 acoustic receivers, making up 6 major acoustic listening lines (see Appendices A1 and A1). Of particular interest for this work are the three lines located (a) near Cape Elizabeth, Washington, (b) across the Strait of Juan de Fuca, and (c) offshore of Brooks Peninsula, Vancouver Island (Figure 1). The equipment on these lines has been almost completely recovered as of late November, 2005, providing data on Snake River Chinook movements. An additional line extending out to the edge of the continental shelf north of Icy Strait, southeast Alaska (see Appendices A1 and A1) will be recovered early in 2006, yielding additional information on the rates of travel and ocean survival of the smolts.

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[1]Bathymetric data: ©2003, Government of Canada, with permission from Natural Resources Canada. Obtained through the GeogGratis web site (http://geogratis.cgdi.gc.ca).
Topographic data: GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/mgg/topo/globe.html) and CD-ROMs.

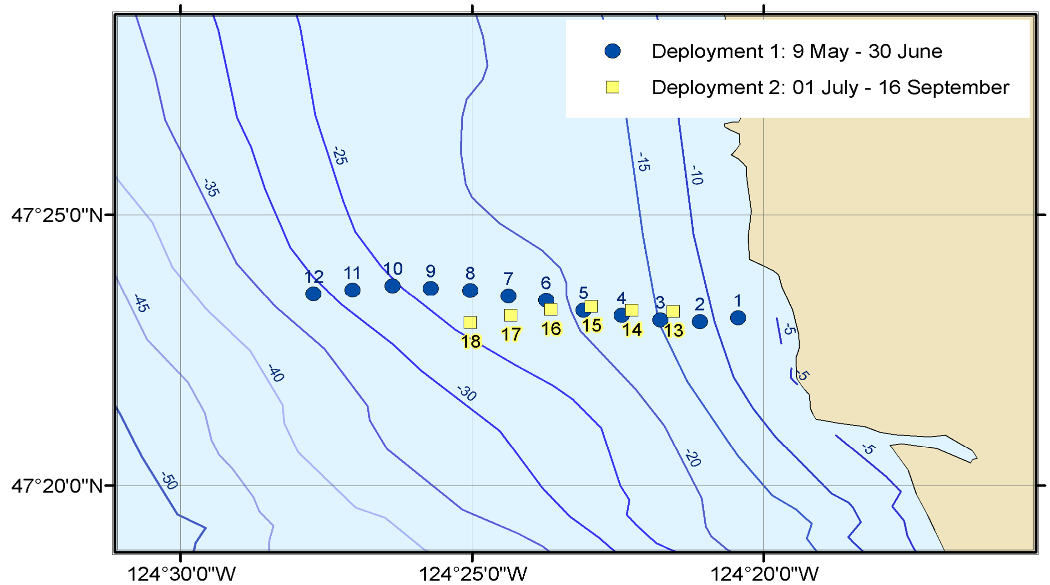

Figure 2. Detail of the placement of acoustic receivers on the Cape Elizabeth line, off the coast of Washington (see also Figure 1). The receivers at stations 1 and 2 were recovered by divers on July 13; the receiver at station 1 had been displaced by 450 m, and prematurely stopped working on June 17. Units 3, 7, 9, 10, and 14 were not recovered. Total length of the line was 9.1 km for the first deployment, and 4.4 km for the second. Bathymetric data courtesy of the USGS[II].

Cape Elisabeth (Grays Harbor) Line

The twelve VR2 acoustic receivers on the Cape Elizabeth listening line were first deployed on May 9, 2005 (Figure 2). Although originally intended to extend across the shelf to the 200m isobath, the line was laid out along only the inner half of the continental shelf because of the unexpected cancellation of the release of compatible tagged smolts by Prof Carl Schreck's group at OSU this year, and because of delays in equipment procurement in the spring. A first attempt was made to recover the equipment on June 30, by which time all migrating smolts were expected to have left the area, and because of particular difficulties at the Cape Elisabeth line owing to the difficult location. Six of the twelve units were recovered successfully, and were redeployed on July 1 after recovering the data files. Four of the six remaining units responded to acoustic "wake-up" calls, confirming that the receivers were still in place and functioning correctly; however, efforts to recover the units were unsuccessful; in most cases both the Kevlar recovery line and ground lines broke because the anchoring systems seem to have been deeply buried under the shifting sand bottom. Two of these units, including one of the two that had failed to respond, were recovered by commercial divers contracted by Kintama Research on July 13, and yielded complete data sets. The non-responding unit was found at approximately 450 m distance from its original deployment site, near shore, and separated from its anchor and badly abraded by wave action; the data file indicated that the unit stopped working on June 17. A final recovery attempt was made on September 16, at which time five of the six units redeployed on 1 July were successfully retrieved. The sixth unit was confirmed to be in place and functioning correctly, but could not be recovered.

[II] Ann E. Gibbs, Maarten C. Buijsman, and Chris R. Sherwood, 2000. Non-Navigational Gridded Bathymetry Data for Washington-Oregon Coast: 1926-1998. Open-file report, obtained through the USGS Publications Warehouse (http://pubs.usgs.gov/of/2000/of00-448).

Although most of the equipment that was deployed remained in place and appeared to have functioned normally throughout the deployments, wave action and high sediment loads in this area produced considerable difficulties in retrieving the equipment. With the current generation of Vemco acoustic tracking units (the VR-2), this resulted in the loss of the data stored on the units, as a necessary step in data recovery from the units is physical recovery of the VR-2 to the surface and onto the boat in order to download the data. Failure of the acoustic releases on three units made it necessary to recover them by grappling for the ground line connecting units on the listening line. Of the remaining receivers, some appeared to have become fixed in place by moving sediment covering the anchoring system and causing the Kevlar recovery line to break, again requiring recovery by grappling. While this approach made it possible to recover 75% of the receivers that could not be retrieved normally, in some cases the ground line was found to have been chafed through as a result of the combined effects of wave action and sand abrasion (or cut by crab fishermen whose gear might have become entangled in the ground line).

Strait of Juan de Fuca Line

A total of 27 acoustic receivers were deployed across the Strait of Juan de Fuca between April 4 and April 15, 2005 (Figure 3), and recovered in late October. These provided almost complete coverage of the Strait, except for a 1 km gap in the middle of the line resulting from an equipment malfunction during deployment of the line (Figure 3). Despite very high failure rates of the acoustic releases,(due to a technical problem reported by the manufacturer to us only after the units were deployed), all but one unit was recovered using either the acoustic releases that did function correctly or by grappling for the ground line where the acoustic releases failed. The location of the last unit was confirmed, but the instrument could not be recovered. While some units were found to have been displaced by fishing gear, in most cases the spacing between neighbouring receivers remained small enough to continue providing nearly complete coverage of the Strait. The only significant exception is a receiver that broke loose entirely (the sixth from the US shore line in Figure 3), most likely in early- to mid-August; however, all Snake River Chinook were likely past by this time. In addition to the units deployed this spring, three receivers that had remained in place at the end of the 2004 field season were located and recovered; as two of three had continued to function through the 2005 field season until recovery 18 months after initial deployment, a level of redundant coverage existed near both shores on the Juan de Fuca line.

Brooks Peninsula Line

Eight acoustic receivers were deployed partway across the shelf offshore of Brooks Peninsula, Vancouver Island, on 19 April, 2005 (Figure 4). Two additional receivers that had been set aside for this line could not be deployed, reducing coverage of the shelf to the shoreward 80%. As with the Juan de Fuca line, 100% failure of the acoustic releases on these units prevented the normal planned recovery during an initial attempt on 03 October; however, the position of all eight units was confirmed acoustically by triangulating ranges to the surface vessel. A subsequent recovery attempt was made on November 17-21, using both grapples and a remotely operated underwater vehicle on a different chartered vessel during the next available window in the weather; five of the eight units were recovered providing data from 50% of the entire shelf at this site.

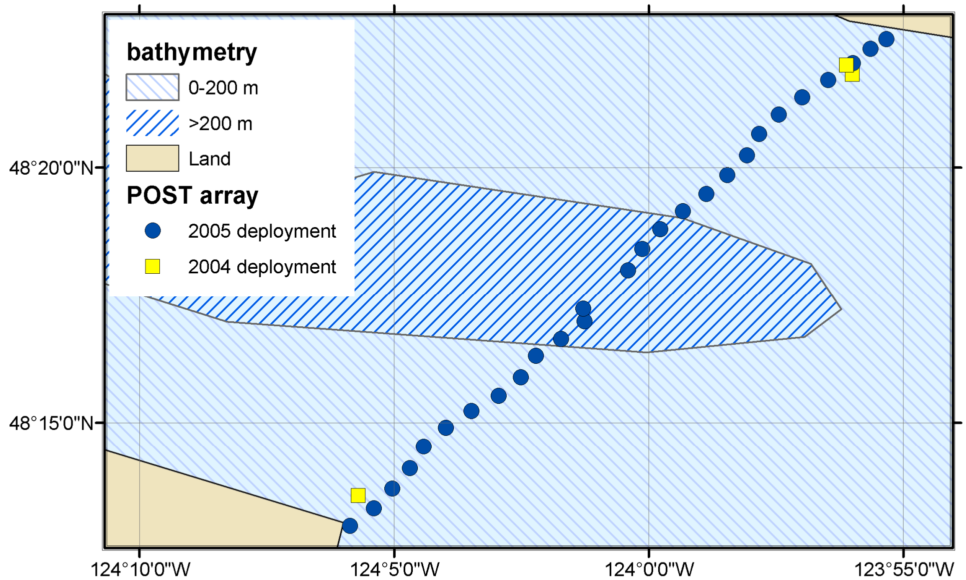

Figure 3. Detail of the placement of acoustic receivers on the Juan de Fuca line (see also Figure 1). The second unit from the northern shore could not be recovered. The fifth unit from the southern shore (not counting the 2004 unit) broke free, most likely in early- to mid-August (after all Snake River Chinook were likely past); however, the unit was recovered with data intact. Note that three units that had remained in place at the end of the 2004 field season were found and recovered this year. Bathymetric data: ©2003, Government of Canada, with permission from Natural Resources Canada. Obtained through the GeoGratis web site (http://geogratis.cgdi.gc.ca).

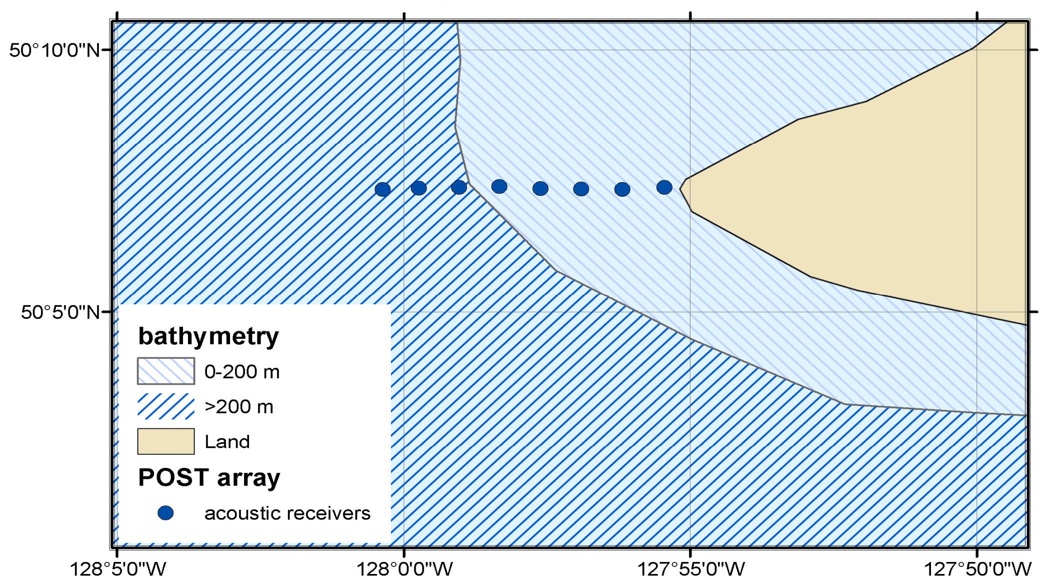

Figure 4. Detail of the placement of acoustic receivers on the Brooks Peninsula line, off northwest Vancouver Island (see also Figure 1). Note that the first, second, and sixth units from shore could not be recovered. Bathymetric data: ©2003, Government of Canada, with permission from Natural Resources Canada. Obtained through the GeoGratis web site (http://geogratis.cgdi.gc.ca).

Northern Strait of Georgia and Queen Charlotte Strait Lines

Both listening lines were recovered in their entirety, although the same failure of the acoustic releases was encountered during the recovery operations. Two units on the northern Strait of Georgia line were pulled up by a commercial prawn fisherman and resulted in a gap in this detection line from 15-20 May, 2005.

Keogh River Receivers

Three receivers were placed off the mouth of the Keogh River, approximately 15 km south of the Queen Charlotte Strait line (see Figure 1). The receivers were put in place on April 18 and recovered on September 26, 2005, without incident. The main purpose of this line during the 2005 field season was to count the outmigrating smolts in order to measure the freshwater survival of Keogh River coho and steelhead. As some smolts either died or remained continuously in the vicinity of the receivers, the potential for false detection of tag codes caused by multiple tags transmitting simultaneously near the Keogh River receivers makes these units slightly less reliable for the purposes of tracking Snake River smolts; this is discussed further in Section 1.1 below. Thus, any detections of Snake River tag codes on this line that are not also observed on at least one of the Queen Charlotte Strait, northern Strait of Georgia, or Juan de Fuca lines should be considered suspect.

Kintama Research is currently concentrating R&D efforts on improving deployment and recovery methods, hopefully increasing success rates in deploying and recovering units on exposed lines such as Cape Elizabeth and Brooks Peninsula to a level comparable with that experienced on the Strait of Georgia lines, for which almost all receivers were successfully recovered. Failure rates for the acoustic releases used this year were disappointingly high; this failure was due to the use of an inappropriate release wire provided by the manufacturer. The correct operation of all releases was verified in Kintama's lab prior to use, but operation in the ocean failed because the releases proved to have insufficient current to melt the burn wire and release the bottom unit in seawater, probably because some of the current shorted through seawater. This will be addressed in time for next year's work, either by correcting the technical problem identified by the manufacturer or by re-engineering the deployment system altogether. Additionally, field testing of new long-lived VR3 acoustic receivers equipped with underwater acoustic modems during 2005 was completed successfully; such units will allow for data recovery from any functioning receiver, without physical recovery of the unit

OBSERVATIONS

1.1 Detections of Snake River Chinook on the POST Array (Alaska Excluded)

Of the 198 Snake River chinook barged and released below Bonneville dam, 19-20 (range explained below) have been detected on the POST array as of late November, 2005. Three tags were detected on the Cape Elizabeth line approximately one week after release, two at or near the offshore end of the line (Table 1, Figure 5). One additional tag was detected on two separate sections of the Juan de Fuca line approximately one month after release; as this tag was not heard on any of the POST lines within the Strait of Georgia, this appears to suggest that the smolt circled over the Juan de Fuca line and returned to the outer coast, likely continuing its northward migration. Fifteen tags were detected on the Brooks Peninsula line 27-45 days (average of 35 days) after release. None of the tags heard on the Brooks Peninsula Line were previously detected on the Cape Elizabeth or Juan de Fuca Lines (Table 1, Figure 5), nor were the tags heard on the southern lines subsequently heard on the Brooks Peninsula line.

Two additional Snake River tag codes were recorded on acoustic receivers at the mouth of the Keogh River, northeast Vancouver Island. One of these, tag # 3881, is known to be a false positive, appearing as a single record too soon after release for a Chinook to have covered the required distance (Table 1); this was likely a result of a tag collision, resulting from overlapping transmission of multiple tag IDs in the vicinity of the Keogh Receiver during the Keogh River coho run. This may or may not also be the case with the second tag (#3930); while the date, location, and transmission environment of the detection make it suspect, it is not possible to completely rule out the possibility that it actually corresponds to a valid Snake River tag. However, the fact that it was not detected on either the Juan de Fuca and Strait of Georgia lines to the south or the Queen Charlotte Strait line to the north makes it unlikely that this was a true detection.

Given the numbers of detections at or near the outer end of the acoustic listening lines at Cape Elizabeth and Brooks Peninsula (Figure 5), it is almost certain that additional Snake River chinook fish migrated to the west of these lines undetected, so that the above numbers underestimate ocean survival. Based on 50% coverage of the continental shelf offshore of Brooks Peninsula, survival to this point is likely closer to 15.2%, approximately one month after release of the smolts into the Columbia River. In order to obtain a more reliable estimate, both listening lines need to be extended out to the shelf break and all of the data recovered.

In addition to the detections of Snake River chinook smolts, large numbers of additional POST and non-POST tags were detected on the acoustic listening array (Figure 6 through Figure 9). For example, 63 non-POST tags were detected on the Cape Elizabeth line; based on tentative identifications of non-POST tags (pending confirmation by tag owners), most of these tags (all but 8) were likely implanted into sturgeon. In addition, 25 of the probable sturgeon that were recorded on the Cape Elizabeth line were also recorded on the Brooks Peninsula line, providing rate of travel information on these species as well. In all cases, significant numbers of fish were detected along the entire length of the listening lines (Figure 6 - Figure 9), including near the ends of the Cape Elizabeth and Brooks Peninsula lines, again demonstrating the need to extend these lines further offshore.

Table 1. Summary of acoustically tagged Snake River smolts detected on the POST array as of end of November, 2005. All fish were released into the Columbia River, 4 km downstream of Bonneville Dam (45º37'44"N, 121º58'10"W, see Figure 1) at 07:10 on May 22, 2005 (GMT). "Offshore" distances on the Juan de Fuca line are measured from the Canadian shore (i.e., east-to-west, consistent with the other two lines). Note that both of the tag codes recorded on the Keogh River receiver are believed to be false positives caused by the unusual detection environment there caused by multiple tags continuously transmitting in range of the receivers for long periods of time.

Acoustic listening line	Tag ID code	Fork length (mm)	Total # of tag Xmis-sions	Time of detection (GMT)			Distance offshore (km)		
				Minimum	Mean	Maximum	Min	Mean	Max
Cape Elizabeth	3847	158	25	30/05/05 21:07	30/05/05 21:27	30/05/05 21:49	9.3	9.3	10.1
	3866	150	130	30/05/05 20:49	31/05/05 02:46	01/06/05 02:59	3.4	3.8	5.1
	3938	144	9	29/05/05 22:33	29/05/05 22:41	29/05/05 22:47	9.3	9.3	9.3
Juan de Fuca	3846	152	45	24/06/05 01:18	24/06/05 10:50	24/06/05 16:11	12.4	14.5	17.9
Brooks Peninsula	3798	151	11	20/06/05 17:49	20/06/05 18:00	20/06/05 18:06	5.5	5.5	5.5
	3800	167	1	25/06/05 09:41	25/06/05 09:41	25/06/05 09:41	3.8	3.8	3.8
	3808	142	1	18/06/05 03:01	18/06/05 03:01	18/06/05 03:01	6.2	6.2	6.2
	3814	146	1	28/06/05 19:27	28/06/05 19:27	28/06/05 19:27	3.8	3.8	3.8
	3818	154	14	14/06/05 16:57	14/06/05 17:04	14/06/05 17:12	3.8	3.8	3.8
	3832	147	4	01/07/05 10:55	01/07/05 10:59	01/07/05 11:01	5.5	5.5	5.5
	3859	153	77	02/07/05 04:36	02/07/05 08:10	02/07/05 09:19	3.8	5.7	6.2
	3865	146	32	01/07/05 18:53	01/07/05 19:16	01/07/05 19:33	3.8	3.8	3.8
	3879	146	18	26/06/05 16:47	26/06/05 16:58	26/06/05 17:07	5.5	5.5	5.5
	3891	157	15	19/06/05 05:33	19/06/05 05:41	19/06/05 05:49	2.9	2.9	2.9
	3895	145	4	06/07/05 12:01	06/07/05 12:07	06/07/05 12:10	5.5	5.5	5.5
	3899	159	3	22/06/05 15:47	22/06/05 15:49	22/06/05 15:51	6.2	6.2	6.2
	3907	152	7	29/06/05 17:31	29/06/05 17:36	29/06/05 17:40	2.9	3.1	3.8
	3929	156	7	28/06/05 16:11	28/06/05 16:22	28/06/05 16:36	5.5	5.6	6.2
	3952	147	4	18/06/05 08:23	18/06/05 08:27	18/06/05 08:31	5.5	5.5	5.5
Keogh River	3881	142	1	26/05/05 18:15	26/05/05 18:15	26/05/05 18:15	-----	-----	-----
	3930	159	10	03/06/05 07:04	21/06/05 10:40	23/07/05 21:35	-----	-----	-----

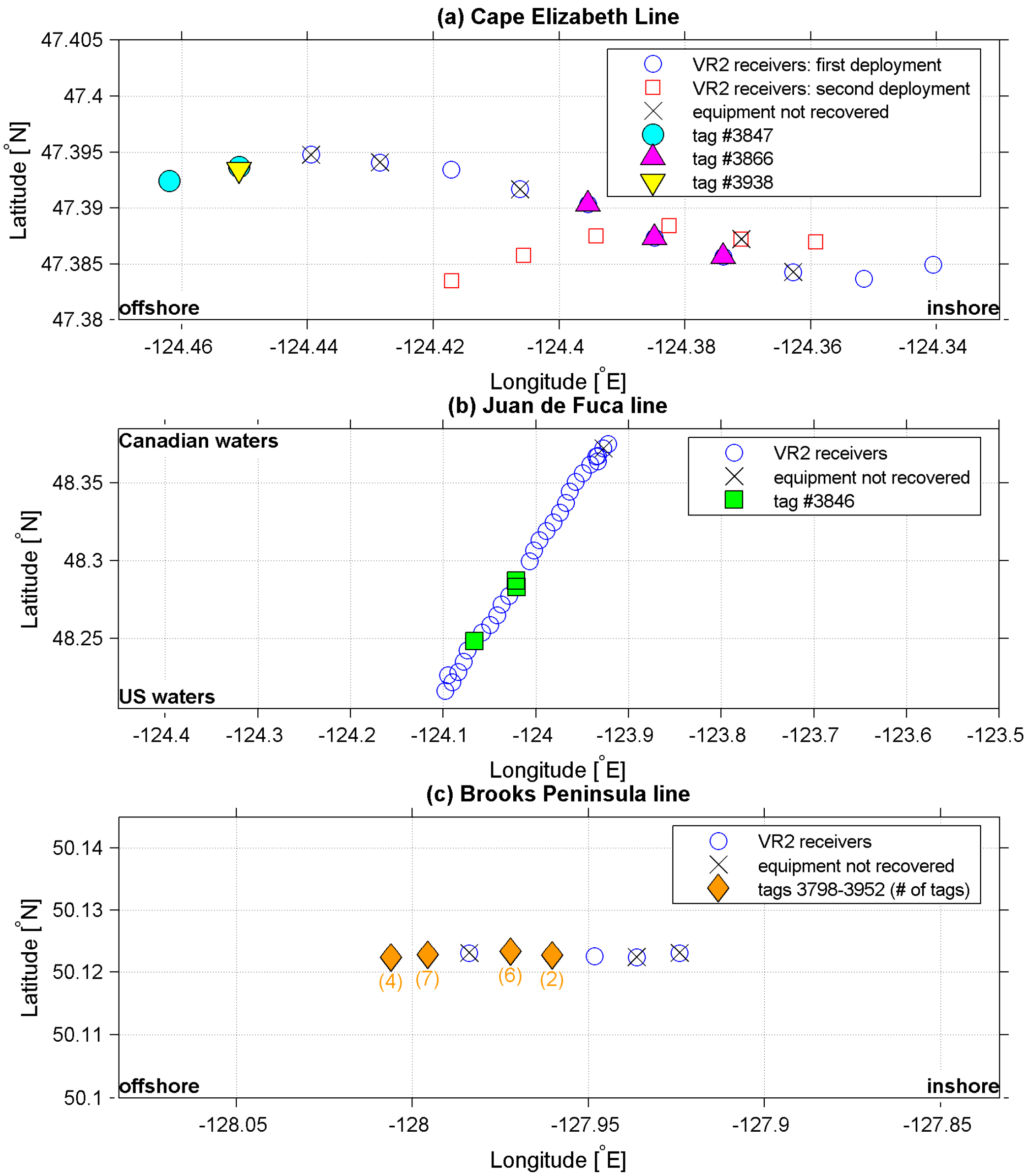

Figure 5. Locations of Snake River Chinook detected on the Cape Elizabeth (a), Juan de Fuca (b), and Brooks Peninsula (c) acoustic listening lines. The first deployment of receivers on the Cape Elizabeth line covered the period between May 9 and 30 June; exceptions are the receivers at station #1, which stopped working on June 17 and was found 450 m off-station, and the receiver at station #2, which was recovered (working) on July 13. The second deployment covered the period between July 01 and September 16, and yielded no detections of Snake River Chinook. Juan de Fuca and Brooks Peninsula receivers were in place between early April and mid- to late October. Note that the number of unique tags detected at each station on the Brooks Peninsula line is labelled below the station markers in panel (c).

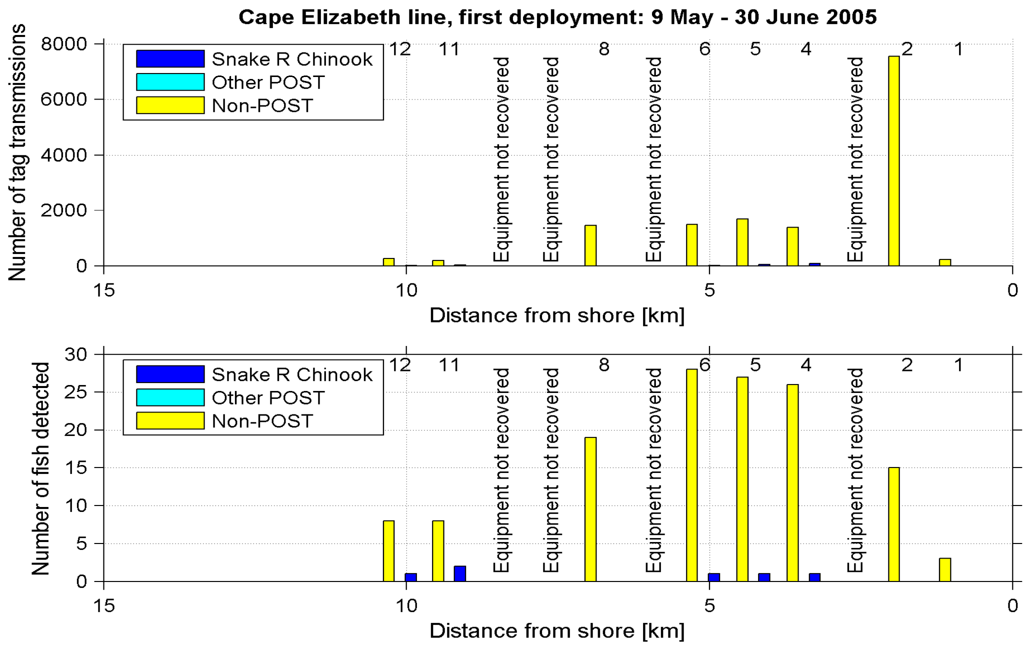

Figure 6. Number of tags transmissions and unique fish detected during the first deployment of acoustic receivers on the Cape Elizabeth line. Data are plotted by station, with station numbers labelled at the top of each panel (see also Figure 2). See Section 0 for details regarding recovery dates at stations 1 and 2. Note that 87% of the tag transmissions shown at station 2 correspond to one of three sturgeon, which remained in the vicinity of the line longer than the remaining fish.

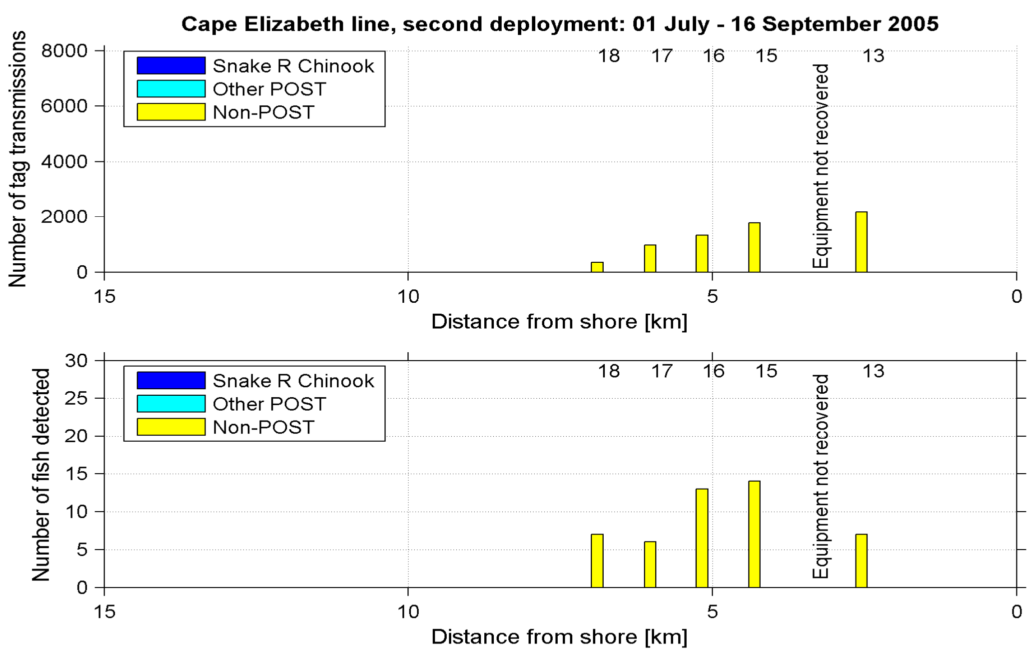

Figure 7. Number of tags transmissions and unique fish detected during the second deployment of acoustic receivers on the Cape Elizabeth line. Data are plotted by station, with station numbers labelled at the top of each panel (see also Figure 2). POST tags were not detected on the Cape Elizabeth line during this deployment.

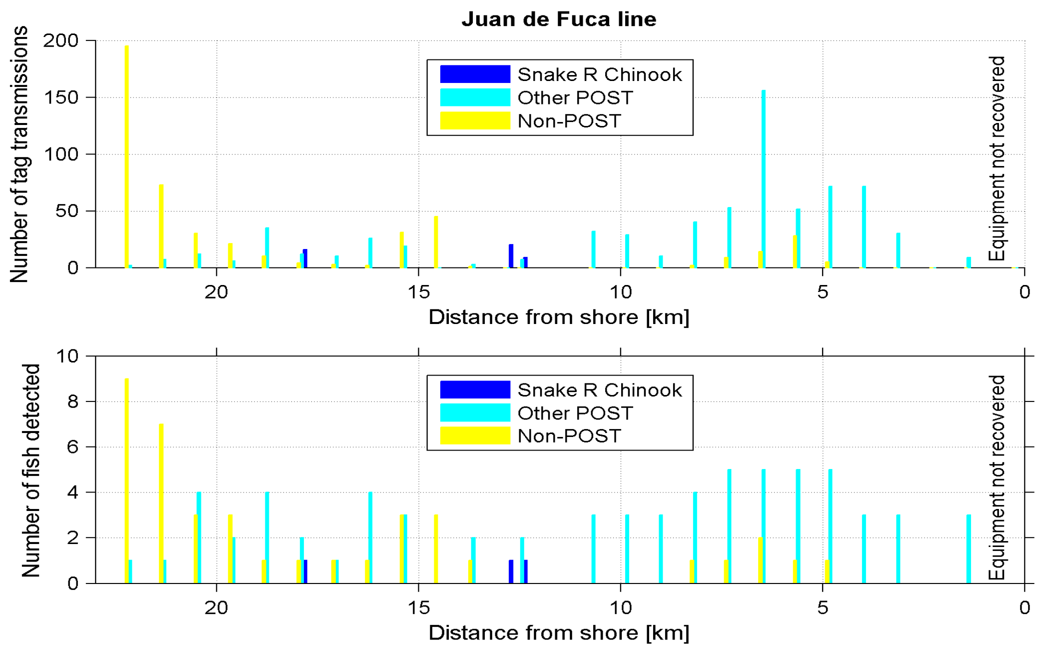

Figure 8. Number of tags transmissions and unique fish detected on the Juan de Fuca acoustic listening line. Data are plotted by station, with distances calculated from the Canadian shore (see also Figure 2). Note the single Snake River fish at receivers 12.4 km, 12.8 km, and 17.9 km from shore (see Figure 5).

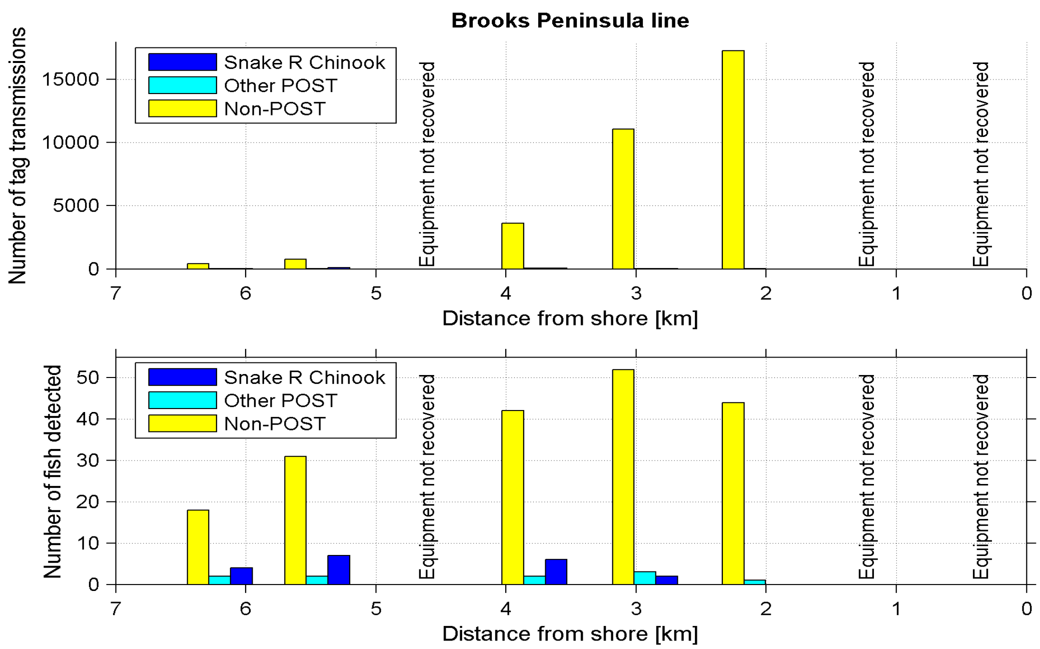

Figure 9. Number of tags transmissions and unique fish detected on the Brooks Peninsula acoustic listening line. Data are plotted by station (see also Figure 2, Figure 5).

1.2 Rates of Travel

As in 2004, rates of travel for the Snake River chinook smolts are high, with average rates over 25 km/d, or almost 2 body lengths per second (Table 2). These numbers may overestimate typical rates of travel in the ocean; as noted in the 2004 annual report, initial downstream migration from Bonneville dam to the Columbia River mouth has been observed to be particularly rapid, with fish leaving the river approximately four days after release (Ben Clemens, personal communication[III]), i.e. an in-river rate of approximately 56 km/d. This suggests a lower value of approximately 20 km/d (1.5 BL/s) for a typical migration rate at sea, which still indicates a rapid and focussed migration (Table 2). Travel to the Cape Elizabeth line was particularly rapid, and slowed slightly as fish continued toward Brooks Peninsula. Travel for the single fish observed on the Juan de Fuca line appeared to be both slower and less directed than that of its peers.

Once the Snake River chinook have passed the Brooks Peninsula line, the smolts must migrate an additional 1,100 km before reaching the southeast Alaska line, near Icy Strait (see Appendix A1). Based on an average rate of travel of 20 km/d, this distance would be covered in slightly less than two months, with fish arriving at the Alaskan listening line in late August and early September. Based on a tag transmission life of approximately 4.5 months (a conservative estimate, based on manufacturer's specifications for the batteries), tags are expected to continue transmitting until at least late September. Assuming rates of travel do not slow between Brooks Peninsula and southeast Alaska, this should be sufficient to detect all but the slowest smolts as they migrate along the Alaskan continental shelf.

*Table 2. Rates of travel of Snake River Chinook detected on the POST array. Distances are estimated for the shortest reasonable paths along the continental shelf. It is assumed that fish that were not detected on the Cape Elizabeth line travelled immediately offshore of it. *Keogh River detections: One or both detections may be false positives (see Section 1.1); speeds are shown for travel around the northern tip of Vancouver Island (based on the absence of detections within the Straits of Georgia and Juan de Fuca), but are excluded from calculations of average values in order to avoid biasing the mean.*

Acoustic listening line	Distance from release point (km)	Number of fish detected on the line	Average rate of travel (min-max)			
			Assume constant rate of travel from release		Assume 56 km/d travel to the river mouth	
			km/d	BL/s	km/d	BL/s
Cape Elizabeth	353	3	42.9 (41.1-46.3)	3.31 (3.02-3.72)	30.7 (28.0-35.7)	2.37 (2.08-2.87)
Juan de Fuca	526	1	16.1	1.22	10.5	0.8
Brooks Peninusla	752	15	22.7 (16.7-32.1)	1.74 (1.33-2.41)	18.2 (12.8-27.2)	1.39 (1.02-2.04)
Keogh River*	925	2	142.2 (77.1-207.3)	11.25 (5.61-16.90)	87.7 (87.7-?)	6.38 (6.38-?)
All detections (excluding Keogh River)*		19	25.5 (16.1-46.3)	1.96 (1.22-3.72)	19.8 (10.5-35.7)	1.52 (0.8-2.87)

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CONCLUSIONS

On May 22, 2005, 198 acoustically tagged Chinook smolts were released into the Columbia River, 4 km downstream from Bonneville Dam. Tracking of the smolts on the POST acoustic array yielded the following results:

- A total of at least 19 of the 198 tagged Chinook smolts (10%) were detected on the POST array. Three of these were observed on the Cape Elizabeth line, one in the Strait of Juan de Fuca, and fifteen offshore of Brooks Peninsula. One more fish may have been detected briefly near the mouth of the Keogh River, northeast Vancouver Island.

- Fifteen smolts (7.5%) were detected on the Brooks Peninsula line, approximately one month after release. Correcting for 50% coverage of the continental shelf by this line, survival to this point is probably double this value, i.e. 15%. As smolt to adult survival is often only 0.5%, this value indicates that possibly only one of thirty (~3%) Snake River chinook reaching Brooks Peninsula might survive to return as adults. This suggests that substantial mortality may occur later in the life history.

- Average rates of travel from Bonneville dam to the acoustic listening lines were quite high, over 25 km/d or almost 2 BL/s. This is consistent with the rates observed in 2004. Even adjusting for faster travel in the Columbia River, rates of travel were likely close to 20 km/d or 1.5 BL/s. The fastest rates were observed in the three fish on the Cape Elizabeth line (average rate of 43 km/d from the release site), while the fish detected on the Juan de Fuca line travelled slower than average (16 km/d).

- Based on estimated rates of travel, the remaining battery life of the acoustic tags should allow for detection of smolts crossing the southeast Alaskan listening line as late as the end of September. Data on these smolts will be available when this line is recovered in December or January.

- Because of a combination of factors involving cancellation of an acoustic tagging project using Vemco equipment by Dr Carl Schreck and problems with equipment recovery, incomplete coverage of the continental shelf occurred on the Cape Elizabeth and Brooks Peninsula lines in 2005. Because fish were detected near the outer end of both lines, we recommend extending the acoustic listening lines out to the shelf break in future, in order to detect all smolts migrating up the coast. (The Alaska line extends the full width of the shelf).

- In addition to the Snake River fish listed above, large numbers of additional POST and non-POST tags were detected on the listening array. Although the identity of the owners of tags coded with non-POST tag coding are not available from the manufacturer Vemco without receiving prior permission of the original tag purchaser, a number of these tags are likely to have been implanted into sturgeon in various regions of the US West Coast. A total of 34 "non-POST" tags were detected on multiple acoustic lines, mainly (N=20) moving south to Cape Elizabeth from Brooks Peninsula, but with some (N=14) moving north. A total of 9 of these tagged fish were observed to shuttle back and forth between these lines, with northwards speeds (37.0±2.8 km/d) almost six times the speed of southward movements (6.9±12.3 km/d; mean±SD). Although the identity of these tagged fish is uncertain at this time, the data provides a useful demonstration of the power of the POST array to repeatedly track the wide ranging shelf-wide movements of tagged animals (including salmon) over long periods of time.

In summary, almost all equipment deployed in the 2005 field season was confirmed to have remained in place and operated successfully throughout the deployment. Mechanical problems described for the 2004 field season were successfully addressed. However, some new issues occurred, with a combination of wave action, moving sand, and fishing-related damage making it difficult or impossible to recover some instrumentation. As a result, some “holes” in the acoustic lines occurred. These issues should be rectified in time for the 2006 field season, as R&D work in 2005 has validated a new long-lived (6-7 yr) acoustic receiver with remote data access capability. This wireless capability should bring the effectiveness of the Cape Elizabeth line on par with that observed on other parts of the POST array, since almost all unrecovered units are known to have remained in place on the seabed. Wireless recovery of the stored data should substantially improve the effectiveness of the listening lines.

ACKNOWLEDGEMENTS

Considerable assistance was provided by Mr. John McKern and the Army Corps of Engineers, who provided assistance with land and barge transportation, respectively, of the chinook smolts from the Kooksia hatchery to the release site.

Appendices

A1 Summary of 2005 POST detection data

The numbers of tagged fish detected on the POST array during the 2005 field season are shown in Table 3, for the acoustic listening lines shown in Figure 10. A total of 626 distinct acoustic codes, including 472 known POST tags, were heard on the POST array as of late November, 2005, with more expected when the remaining listening lines in the Englishman and Fraser Rivers and in southeast Alaska are recovered later this year.

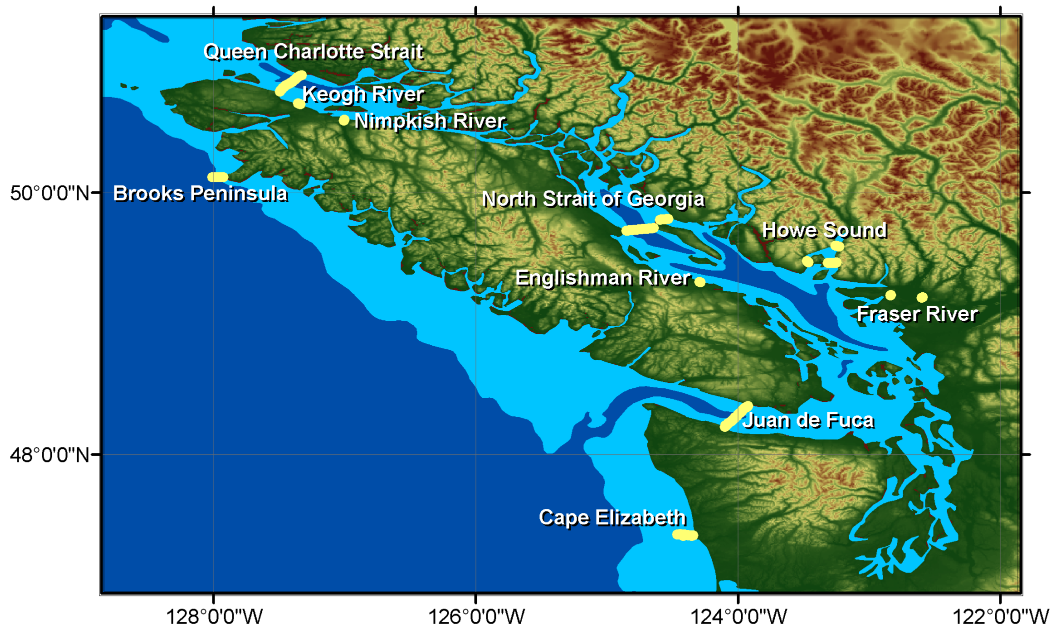


Figure 10. Locations of acoustic listening lines deployed during the 2005 field season. An additional line located near Icy Strait in southeast Alaska is not shown. Bathymetric and topographic data courtesy of the Government of Canada and NOAA, respectively[IV].

[IV]Bathymetric data: ©2003, Government of Canada, with permission from Natural Resources Canada. Obtained through the GeogGratis web site (http://geogratis.cgdi.gc.ca).
Topographic data: GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/mgg/topo/globe.html) and CD-ROMs.

Table 3. Summary of the numbers of tags detected on the POST array during the 2005 field season. Lines in the Englishman River and in southeast Alaska, as well as additional receivers in the Fraser River, are scheduled for recovery after the writing of this report. Note that some equipment on the Cape Elizabeth, Brooks Peninsula, and Juan de Fuca lines could not be recovered, potentially reducing the numbers of fish detected at these locations. Line locations are shown in Figure 10. Note that (*) in the table above indicate potential false detections.

Species	Stock	Hatchery or Wild?	# of fish tagged	Number of fish detected at the river mouth			Number of fish detected on marine POST lines						
				Fraser River	Keogh River	Nimpkish River	Howe Sound Inner	Howe Sound Outer	JDF	Cape Elizabeth	NSOG	QCS	Brooks Pen.
Chinook	Coldwater River	W/H	69	22	0	0	0	0	0	0	1	0	0
	Nicola River	H	50	16	0	0	0	2	1	0	1	0	0
	Snake River	H	198	0	2*	0	0	0	1	3	0	0	15
Coho	Cheakamus River	H	100	0	0	0	68	60	0	0	13	0	0
	Elwha River	H	8	0	0	0	0	0	2	0	0	0	0
	Keogh River	W	49	0	45	0	0	0	0	0	0	21	0
	Nimpkish River	H	57	0	1	43	0	0	1	0	0	5	0
	Port Coquitlam	H	117	0	0	0	0	0	0	0	0	0	0
	Spius Creek	H	50	4	0	0	0	0	0	0	1	0	0
	Stamp River	H	100	0	0	0	0	1	0	0	0	0	5
Sockeye	Alouette River	H	19	3	0	0	0	0	1	0	0	0	0
	Cultus Lake	H	466	46	0	0	3	9	2	0	43	21	0
	Sakinaw Lake	W	47	2	0	0	1	1	10	0	13	3	0
Steelhead	Cheakamus River	W	49	0	1	0	37	39	0	0	22	13	0
	Coldwater River	W	50	21	0	0	0	0	2	0	1	0	0
	Deadman River	W	57	11	0	0	0	0	3	0	1	0	0
	Englishman River	W	43	0	0	0	0	1	0	0	18	5	0
	Hood Canal	H	50	0	0	0	0	0	12	0	0	0	0
	Keogh River	H	50	0	41	0	0	0	0	0	0	29	1
Other POST	Other POST	?	155	0	1	0	0	0	0	0	0	0	0

A2 Progress Report, July 2005

Pacific Ocean Shelf Tracking Project

David Welch, Chief Scientist

Progress Report, 10 July 2005

Summary

This year's deployment has gone well, despite the usual swarm of technical issues which had to be addressed at the last moment! The success of the acoustic modem and satellite-linked tracking units that have been developed over the past year shows that the basis for a permanent array is now at hand, and that the use of these units should reduce equipment loss, increase data recovery rates, and decrease the costs of physically recovering the array elements. (The cost of the component array elements will rise, however, as these units are more complex).

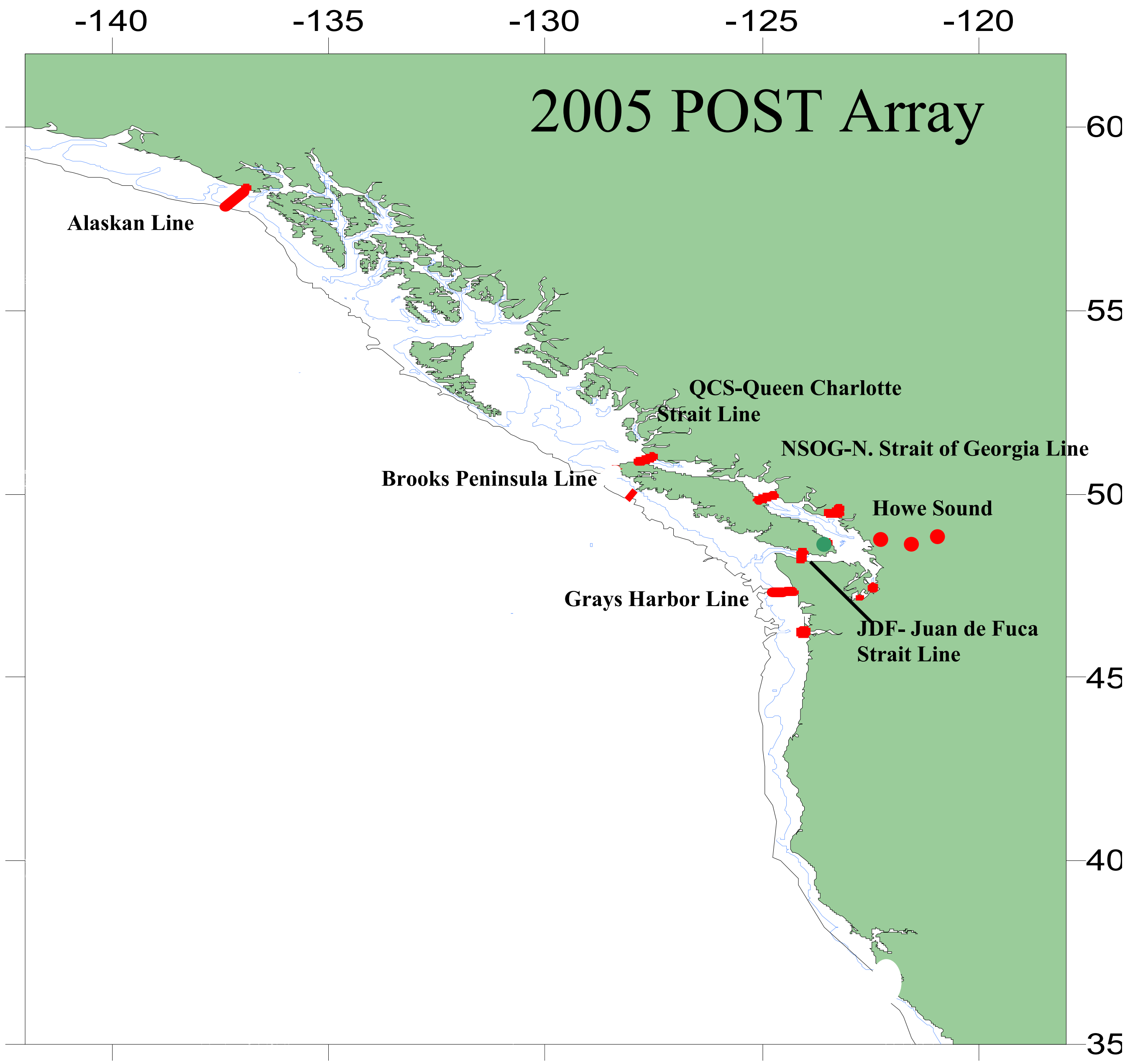
It is now feasible to deploy a permanent year-round tracking array. The strategy of building scientific interest by demonstrating the success of the research has also borne fruit, with POST-coded tags increasing to 230% of last year's total. There is also increasing world-wide interest in the array concept. These results all point to a convergence of scientific interest and demand in the use of the array for addressing previously intractable fisheries research problems. The remainder of this brief update highlights the key items of interest.

The completion of all lines forming POST's 2005 acoustic array was officially achieved in mid-June, 2005, when the acoustic line north of Icy Strait, Alaska, was deployed. At this point, all of the lines deployed in 2004 had been re-deployed, and the Alaskan line had been extended to run entirely across the shelf just to the north of Icy Strait. Because of the remoteness of the location, it required two weeks of travelling to deploy this line. Figure 1 shows the extent of the array deployed (See next page).

Two other changes to the array configuration were made from 2004. The three lines in the Fraser River were changed to two lines in different locations, which we hope will give higher detection rates of smolts migrating down-stream than in 2004. Two satellite-linked VR3 units were also deployed on the lower line, allowing us to test our ability to recover the data remotely via an ARGOS satellite link, and to compare the performance of the VR3-ARGOS units with the VR2s. (The use of satellite linked units is infeasible in most situations, however, requiring the use of underwater modems—see below).

The Fraser River equipment was downloaded on June 30th. The VR3-ARGOS detection rates exceeded the detection rates of the standard VR2 units. However, a 100% detection rate from just two units on a single line was not achieved, indicating the need to place additional sensors mid-river. We will be conducting more tests to establish what changes are required to achieve an essentially complete census out of large rivers such as the Fraser.

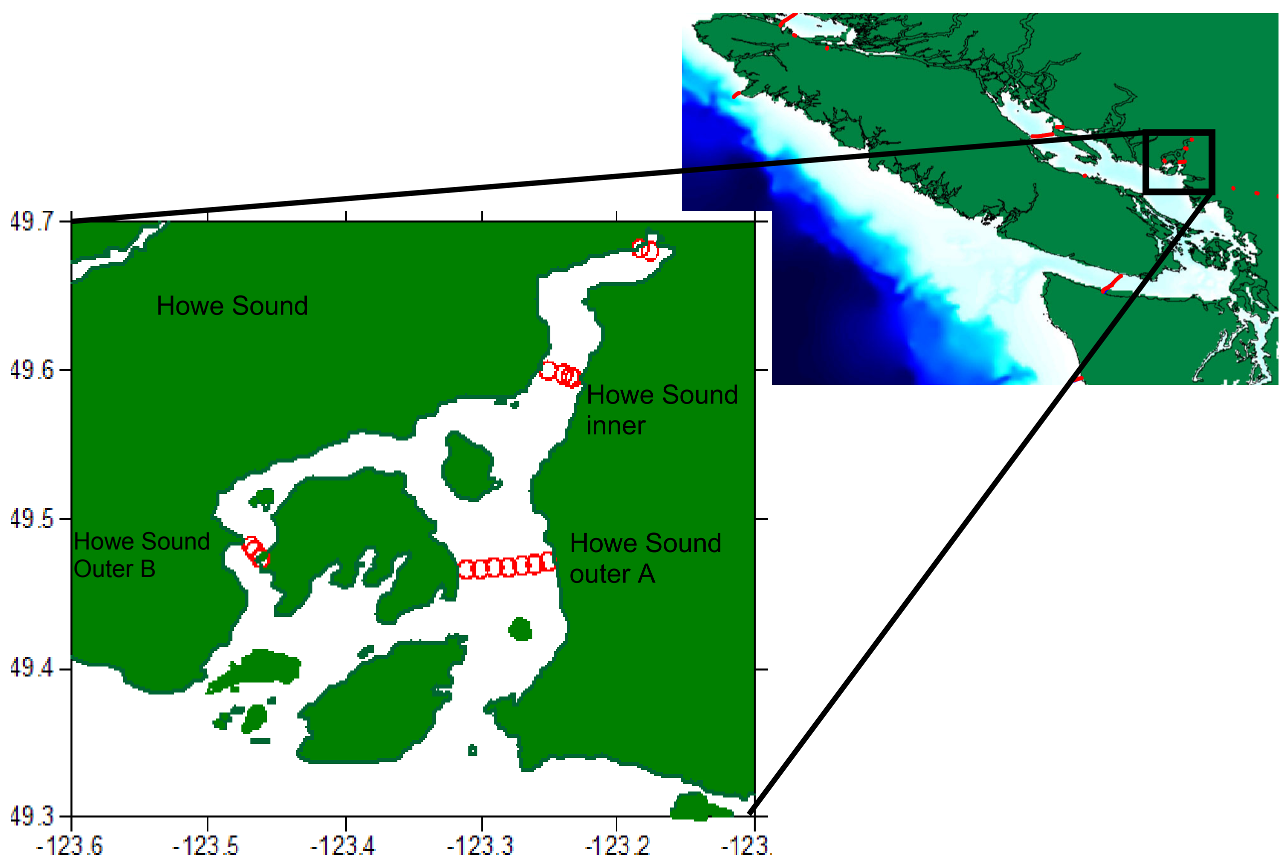
Figure 1. Overall deployment of the 2005 POST array.



The second change we made to the array was to put out a complete sub-array of 14 paired VR2/VR3-UWM (UnderWater Modem) units in Howe Sound (Fig. 2). This is a major test of the VR3-UWM units' performance, and is our third R&D testing cycle since we began evaluating these units (and fixing bugs) last autumn. As of last Thursday, 7 July, I am pleased to report that the entire sub-array performed flawlessly, with complete data upload and excellent performance through the acoustic link. The bottom units were at depths of up to 150m.

The VR3-UWM units thus passed one of two critical tests before they can be considered reliable for roll-out this autumn. The second test of the VR3s was evaluated the following week (July 19-22), when all of the sub-array was recovered to the surface, and the fish detection rates compared with the VR2 sensors also attached to the nodes. If the VR3 detection rates equal or exceed the VR2 rates, then the path forwards for the roll-out of the permanent array is clear. The new sensors matched the performance characteristics of the previous generation. We will also be evaluating a much revised physical deployment methodology which we developed in-house, which we hope will address some deficiencies in the existing approach.

Figure 2. Deployment of the VR2-VR3 underwater modem sub-array under test in Howe Sound.



Tagging Targets

In 2004, POST tagged 1,051 salmon smolts. The current total number of tags ordered for 2005 using the POST code map is 2,673, an increase to 230% of last year's tag totals. This is a very good result, as it demonstrates that the 1,200 tags purchased using Moore or Sloan funds have started to leverage substantial additional tagging research using outside funds.

Tags implanted directly by Kintama total 1,595, an increase to 151% of last year's value. The majority of the remainder have been purchased by a range of outside groups interested in tracking their fish over the array. Some purchased tags were not implanted, primarily because of a power failure at Cultus Lake lab that killed many of the Cultus Lake sockeye that had been intended to be implanted (only 466 of 700 tags could be implanted). A smaller number of tags were left over on some of the river systems because of the difficulty in collecting enough wild smolts for implantation, despite many site visits by the tagging teams to work with the people on the ground. Tag implantation totals for salmon smolt work that Kintama staff were directly involved in are listed in Table 1.

Table 1. 2005 tagging totals for tags directly implanted by Kintama staff.

	Chinook		Coho		Sockeye		Steelhead		Total
Stock	**H**	**W or H**	**H**	**W**	**H**	**W**	**H**	**W**	
Cheakamus R			100					49	149
Cultus Lake					466				466
Englishman R								43	43
Hood Canal							50		50
Keogh R				49			50		50
Nimpkish R				57					57
Coquitlam Reservoir			117						117
Sakinaw Lake						47			47
Snake R. (Columbia)	198								198
Stamp R			100						100
Thompson R (Fraser)	50	69	50					149	318
Totals	**248**	**69**	**367**	**106**	**466**	**47**	**100**	**241**	**1595**

As yet, we do not have a breakdown by the manufacturer of who purchased the remainder of the 2,673 POST tags. In addition, I have been told of an additional 163 tags purchased in the Columbia River with the intent that they can be detected by the POST array, but that are on "Channel B", which is not technically a POST tag channel. (Green sturgeon, detected by POST both last year and this year, are also detected on this channel).

The experimental acoustic array over which the tagged salmon (and other fish) will now move is as shown in Figure 1. The physical span of the array is almost identical to last year, except that, as indicated above, the Alaskan line has been extended fully across the shelf, doubling its extent over last year. Survival post-surgery of tagged animals prior to release has uniformly been reported as excellent, and is similar to last year's high values.

Equipment recovery and data download for most lines will only occur once this year, and the timing depends on the speed with which VR3 acoustic modem equipment is ordered and deployed to replace one or two of the permanent lines.

Results for the Cape Elizabeth (Grays Harbor, Washington) Line

The two exceptions to the strategy of only downloading the receivers in the autumn are the Grays Harbor (Cape Elisabeth) line and the Howe Sound VR3 sub-array. The Cape Elisabeth line was recovered in mid-July and redeployed because of the very exposed location of the equipment. (This line is critical because it is essential to demonstrate the relevance of the POST array to Columbia River salmon problems; last year there were problems where several of the receivers broke free prematurely, preventing an assessment of the line's effectiveness for tracking Columbia River chinook smolts).

Six of 12 receivers deployed in April 2005 were initially recovered. The 6 remaining units that were not recovered resulted from the groundline and/or Spectra recovery lines both breaking during the physical recovery, probably because the anchors are deeply buried in sand. Because communications with the attached acoustic releases was still possible, at least 5 of the remaining 6 units were known to still be in place. A commercial diving firm was contracted to recover the remaining units, as their position was thus clearly known and the location is relatively shallow. The first two near shore units were recovered, but visibility was near-zero and the divers were unable to find the more offshore units—despite being within 4 meters of their location when they dove on them! Recovery attempts on the offshore units was then called off because of the poor conditions and because the key units to recover (those nearest to shore) had been obtained.

A total of only 3 Snake River Chinook smolts were detected on the 8 recovered receivers (of 12 deployed). As the recovered units cover approximately 25% of the width of the shelf, this would imply that only 12 of 200 smolts originally implanted at a Snake River hatchery and then barged to a release point just below Bonneville Dam survived to reach the Cape Elisabeth line, some 380 km from the release site. (Survival to the mouth of the Columbia, 225 kms downstream, is known from previous year's work to be about 50%). This leaves a very large mortality occurring in the ocean north of the Columbia River mouth if these preliminary results are correct.

Although it is not possible to comment in more detail on the Cape Elisabeth line until a complete line is deployed across the shelf, it appears that the equipment is working well—it is the physical recovery that was problematic. The 3 Snake River chinook smolts were all detected moving rapidly northwards and did not return after passing the line (the same behaviour was seen with last year's smolts). This is strong evidence that they are migrating rapidly north away from the Columbia and heading towards the rest of the POST array. When the complete cross-shelf lines of receivers on the Brooks Peninsula and Alaskan lines are recovered this autumn, we should be able to make a more reliable estimate of mortality for this stock.

As with last year, a large number of tagged fish were heard on a "non-POST' channel. It is thus already clear that the POST array is providing broader dividends than just its current application for salmon smolts. Of particular note, are new detections of green sturgeon from the Sacramento River (the only green sturgeon population not detected in last year's work), and a substantial number of repeat detections of green sturgeon that had been detected last year on POST—some of which have now been heard on multiple listening lines and over multiple (2) years. As a final comment, the recovery of a very large amount of data on the green sturgeon all along this line demonstrates that the array technology on the Cape Elisabeth line was working as expected.

Recovery of the remainder of the POST listening array—and the data-- will begin this autumn, probably in September-October. Discussions with the POST SSC will finalise a recommendation as to where to roll out several permanent listening lines over winter (to provide initial assessment of how well the permanent technology is working), and it is expected that these units will be produced in time to replace the temporary VR2 lines, giving us year-round detection capabilities. All data will be made available on the POST website's associated on-line database as soon as the data is organised for input.

Table 1. Summary of tag detections on the Cape Elisabeth (Grays Harbor, Washington) listening line. Data are for the April-early July period, 2005.

Tagging Location	Chinook Smolts	Steelhead kelts	Green Sturgeon	Sturgeon (Species Unspecified)
Columbia River		2		
Snake River	3			
Sacramento R., San Francisco Bay			6	
Currently Unknown				44

A3 Kintama Surgical Procedures

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Pacific Ocean Shelf Tracking: Surgical Protocols for Fish Tagging

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Overview of Surgical Tagging of Fish

Recent technological advances make it feasible to implant fish as small as salmon smolts with ultrasonic tags capable of individually identifying each tagged fish. Identification and tracking of such tagged fish has been demonstrated in river, lake, and ocean environments via the use of listening arrays formed of many acoustic receivers laid out to detect the ultrasonic transmissions of these tags throughout the water column. Such tracking arrays have the potential to be deployed in fresh and salt water bodies on a continental scale, and the recent (2004-2005) demonstration phase of the POST project has demonstrated that by a judicious optimization of tag programming and array geometry it is possible to directly measure movements and survival of salmon smolts in the ocean with a very high degree of accuracy. (The 2004 results demonstrated a 91% detection rate for individual salmon smolts migrating across 20 km long listening lines).

Before any tracking can occur, tags must be successfully implanted into fish, and both tag and fish have to function normally and long enough to be detected by the acoustic array. Implantation of the tag into the body cavity of a fish is considered major surgery and involves significant training and preparation, and also due consideration for the animal's well being. Kintama Research Corporation (KRC) surgeons follow the Canadian Council for Animal Care (CCAC) guidelines and KRC's Standing Operating Procedures, which were developed from veterinary consultation and years of hands-on experience. Implantation of tags is done by surgical teams which consist of two or more members, including at least one senior surgeon. Surgical teams are fully equipped, both in skill and in required materials to handle nearly every scenario encountered in the field.

The surgical process for implantation of the acoustic tag into fish can be broken down into four main steps. These are sedation, induction (anaesthesia), surgery, and recovery. Sedation is a state of numbness or light anaesthesia, and is very important as it aids in preoperative handling of the fish and helps to reduce stress from handling, transport, and immersion into the anaesthetic bath. Minimizing stress is crucial because it can negatively impact immune function as well as behaviour, which in turn can result in the fish being more susceptible to infectious agents, thus potentially reducing survivorship. Handling of fish can also predispose them to infection by disrupting the natural protective exterior mucous layer. So as an extra measure of protection, a synthetic mucous solution is added to all water baths and contact surfaces to help preserve this mucous layer. While under sedation fish are assessed to determine if they are candidates for the surgery. Fish that are deemed acceptable for surgery are transferred to a tank containing a higher concentration of anaesthetic for the purpose of inducing general anaesthesia. Once the fish is fully under it is transferred to a surgical cradle for implantation of the tag. When the surgery is completed the fish is transferred to a recovery tank for observation. Post surgery mortalities are uncommon in smolts in good condition, and in KRC'S experience can be less than 1%.

As with any invasive surgery it is very important to employ aseptic techniques in order to reduce the chance of infection. It is also important to maintain, as close as possible, the fish's normal physiological processes, and to keep ambient environmental conditions stable. To these ends, surgical instruments, tags, and gloves are disinfected prior to surgery and between each fish. The potential for oxygen deficiency (hypoxia) during surgery is eliminated by providing a constant flow of aerated water over the gills. This aerated water also contains a maintenance dose of anesthetic which ensures that the fish remains under general anaesthesia for the entire surgery. The aerated/anesthetic water is constantly recirculated using a pump and other specialized surgical equipment, and its temperature, dissolved oxygen (DO_2) levels, and general quality are continuously monitored using electronic sensors so that they do not fall outside CCAC guidelines. The entire fish is kept wet at all times and a moistened towel is draped over its head to protect it from UV light.

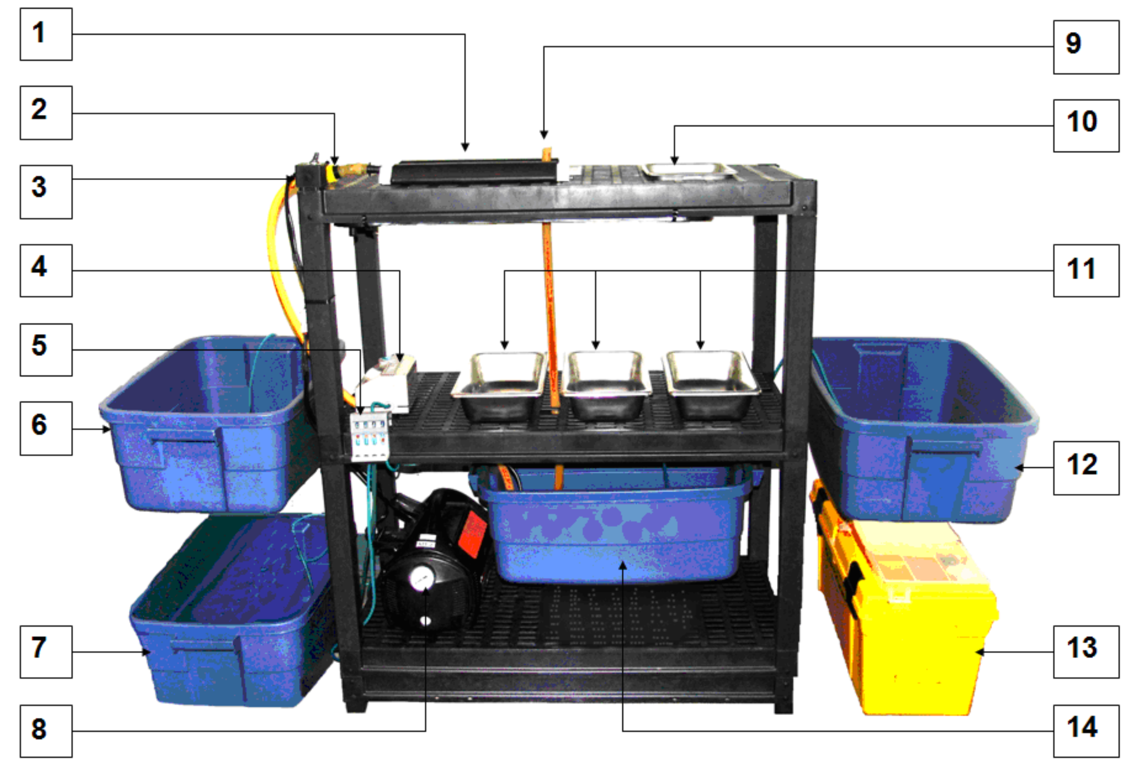
Implantation of the tag is achieved by making an incision through the body wall in the belly of the fish at the mid ventral line, allowing entry into the peritoneal cavity. The acoustic tag is gently inserted through this incision, seated properly, and the incision closed with absorbable monofilament suture material. The fish is then transferred to recovery and typically monitored for approximately twenty-four hours before release.

Portable Surgical Kits

KRC's portable surgical kits are comprehensive and provide the surgical teams with all the required materials necessary to complete the surgeries. Everything, from drugs (seadatives & anaesthetics), surgical tools and tables, to portable shelters and battery supplies is provided in each kit, allowing the surgical teams to work in remote locations and poor weather, while still maintaining high surgical standards.

The design of the surgical kits is kept simple and modular. Complete setup of a kit usually takes about thirty minutes but can be reduced to several minutes depending on the situation. For example, when only a few fish will be operated on and/or the surgeries are to be performed in a remote location, the surgeries can be performed without the need for battery operated pumps and aeration.

The core components of the surgical kit are the surgical cradle, collapsible/height adjustable table, stainless steel surgical trays, aeration system, battery pack, recirculation reservoir, sedation bath, anaesthesia bath, recovery bath, and surgical supply box containing all required surgical supplies (see below). Wherever possible, all components are made from synthetic materials or surgical-grade stainless steel to avoid problems with corrosion and to facilitate disinfection of the surgical set-up.



1)	Surgical cradle	8)	Battery pack
2)	Recirculation pressure valve	9)	Drain tube
3)	On/Off switch for recirculation pump	10)	Surgical instrument tray
4)	Air compressor	11)	Disinfection/rinse trays
5)	Air line multi-valve	12)	Recovery bath
6)	Induction bath	13)	Surgical supply box
7)	Sedation bath	14)	Recirculation reservoir (to maintain anaesthesia during surgery)

The surgical table includes cut-outs for routing the plumbing required for the recirculation system, a drip tray, and attachment points for the electrical wiring which delivers power to the recirculation pump and air compressor. The surgical cradle holds the fish during surgery and is designed to keep the gills submerged throughout the procedure. Water from the recirculation reservoir, containing a maintenance dose of anaesthetic, is pumped into the head of the cradle where it then flows down past the head and gills and along the length of the fish. The water then exits via a drain tube at the opposite end of the cradle. Water flow is adjusted using a valve at the head of the cradle and the water level in the cradle is controlled via a stand-pipe at the exit drain tube. Water level is adjusted to allow the gills to remain bathed by flowing water while allowing the abdomen to protrude from the water, thus preventing water from entering into the abdominal cavity through the surgical incision.

The tools required for the surgeries are a pair of cutting needle drivers, scalpel, suture guide/shield, and surgical probe (Fig. 1). Two complete sets of these instruments are rotated during surgeries so that one set sits in one of three stainless steel trays containing Ovadine™ for disinfection, while the other set is being used for surgery. The other two stainless steel trays contain distilled water and are for rinsing the instruments free of Ovadine™ prior to use on the next fish.

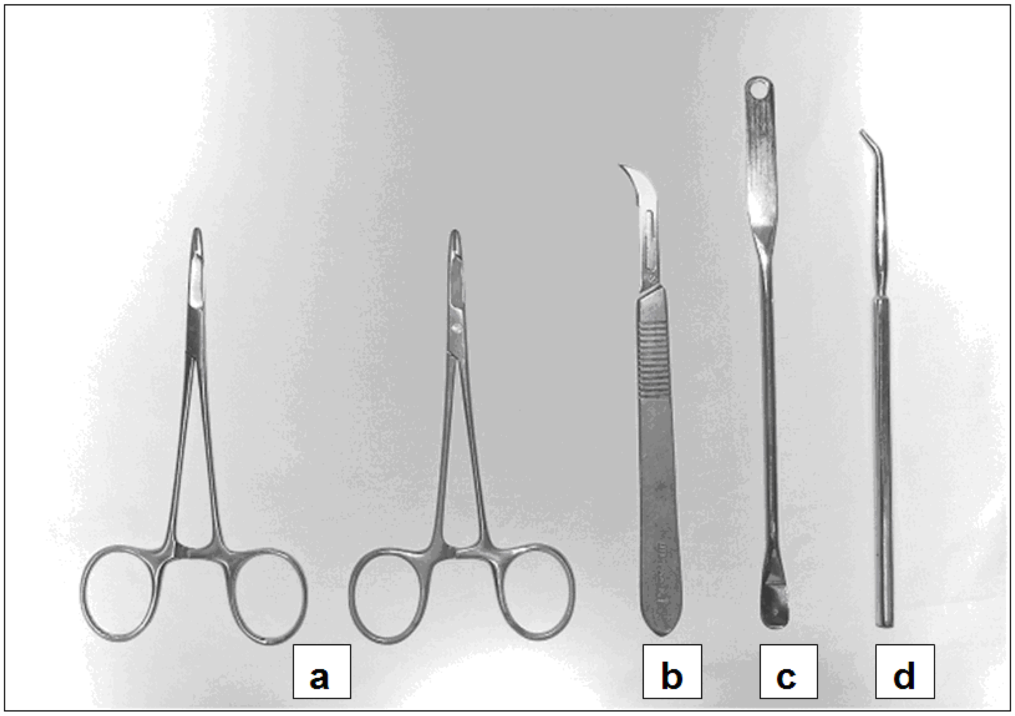


Fig. 1 - a) Needle drivers b) Scalpel c) Suture guide / shield and d) Probe

Anaesthesia

As per CCAC guidelines, only fish of appropriate size are considered for surgery. Fish deemed acceptable are typically first sedated with Metomidate (Aquacalm™); a sedative which helps to reduces stress, prior to handling or transport. In addition, a synthetic mucous (Vidalife™) is used to help preserve the natural protective mucous layer of the fish. General anaesthesia is achieved by using Tricaine Methane Sulphonate (MS-222™). Proper anaesthesia depends on water temperature, water hardness, salinity, oxygen concentration, the biomass and species of fish, and the length of time of immersion. Surgeons generally rely on their experience with the anesthetic and visual cues from the fish, rather than relying on strictly set dosages. However, in general the dosages required fall around 70ppm for induction into general anaesthesia and 50ppm for maintenance during surgery. As surgeries progress for a group of fish 5ml quantities of MS-222 are periodically added to compensate for loss due to metabolization of the drug. The acidity of MS-222 is buffered using stock solutions of sodium bicarbonate dissolved in water.

Implantation of Tags

Pre-operative preparation is generally accomplished through isolating the animals in a tank of their own and allowing them to acclimate to the new environment. Though it is not always possible to isolate the fish, it is helpful to do so because it gives the surgical teams an opportunity to assess the general health of the selected fish, based on how well they tolerate the transfer and subsequent acclimate to the new tank. If further handling is involved, such as in the case of size grading fish, the surgical teams can more closely examine the fish for signs of stress and/or disease. As handling subjects the fish to some level of stress, sedatives should be used to help minimise stress. This is very important because stressed fish are potentially unhealthy fish, with decreased vitality and increased susceptibility to disease, especially when combined with the stress of surgery. Whenever possible, fish deemed acceptable for surgery should not be fed for approximately twenty-four hours prior to surgery. This ensures that the fish have eliminated most of their gastric content, which helps because surgery on fish with full guts can be more difficult. (With wild-caught fish this is frequently more difficult, since the traps used to capture the smolts also capture and accumulate their prey).

Surgical tools and all surfaces should be disinfected with Ovadine™ prior to use, and surgical instruments are disinfected between each fish during surgeries. The surgical process is as follows:

1) Source water temperature and oxygen level are recorded on data sheets, along with general observations for that day;

2) Fish are transferred from source tank to the sedation bath and left covered and undisturbed for approximately ten minutes;

3) Individual fish are taken from the sedation bath and put into the anaesthesia (Induction) bath at about three minute intervals. This is about the time it takes for an experienced surgeon to complete the surgical implantation of the tag.

4) The fish remains in the induction bath until stage four or five anaesthesia is reached (Appendix A).

5) Once properly anesthetised, the fish can be measured (fork length and/or weight) and then transferred to the surgical cradle.

6) In preparation for surgery, the fish is placed ventral side up in the cradle with its mouth around the recirculation water output nozzle. The output nozzle and tubing is made from supple latex tubing so that the fish's mouth and teeth can grab on to it, thus helping to maintain position of the fish and proper water flow during surgery. Further support of especially small fish is accomplished, if necessary, using folded pieces of paper towels that are soaked in water and Vidalife™ and placed along the flanks of the fish to ensure proper positioning of the abdomen.

7) Water flow is adjusted and monitored throughout the surgery to provide a gentle flow through the mouth and over the gills. A properly positioned fish has its head nearly completely submerged with none of the gill lamellae exposed to air. The ventral body wall is above the water line in the cradle only enough to avoid spilling water into the body cavity and a squirt bottle is kept handy to ensure that all exposed parts of the fish remain wet during the procedure.

Extreme care is taken when making the incision in order not to damage any internal organs. The surgeon applies gentle pressure at the incision site by squeezing the belly of the fish with his gloved fingers. This helps to push internal organs down and out of the way of the scalpel blade and facilitates a safer and cleaner cut by helping to better maintain control of the scalpel when the blade cuts or pierces through scales. For smolt-sized Pacific salmon, the incision is made on the mid ventral line and is started several millimeters proximal to the pelvic girdle. The incision is extended cranially just long enough to allow insertion of the tag. Once the incision is completed, a quick visual inspection of the abdominal cavity is made to further assess the fish's condition. For example, the surgeon can see if the internal organs look normal (particularly the spleen), and he/she can see the amount of fatty tissue, and also if the fish is infected with some types of parasites. After inspection, the tag is gently inserted through the opening into the abdominal cavity and is seated lengthwise so that it sits parallel to the mid ventral and lateral lines. Proper positioning of the tag is very important because it helps to reduce pressure points inside the abdominal cavity. Pressure points are sources of chronic trauma and can result in internal damage, frequently in the form of contact necrosis of compressed tissues. If this occurs on the inside body wall or surface of the intestine, either an abscess may form or the tag may be encapsulated, either event possibly resulting in eventual expulsion of the tag. Once the tag is seated properly, the incision is closed with sterile monofilament absorbable suture material using simple interrupted sutures. In smolt-sized fish there is frequently little to no visible bleeding throughout the entire surgical procedure.

Recovery and Holding

After surgery, fish are gently transferred to a recovery tank where they are generally held for approximately twenty-four hours before release. This holding period allows the surgical team, or other persons attending the fish, to visually assess whether or not the fish have returned to normal behaviour patterns before release. Additionally, most mortalities that are the direct result of the surgical procedure occur within this timeframe (probably more as a result of stress, or the effect of the anaesthetic, rather than the actual surgery). Thus, holding the fish ensures that costly tags are not wasted on fish that would have died soon after release, and improves estimates of survival gained by monitoring the animal's movements over the acoustic array. Finally, the holding period is especially valuable to the surgical teams as it provides feedback that can be used to compare against records taken during surgery, thus allowing them to critically assess their work. The fish are released at an appropriate time after consultation with biologists, technicians or hatchery personnel who are most familiar with the release site and the purpose of the biological study, so as to give the fish the greatest chance of initial survival after release. (For example, releasing tagged smolts at dusk reduces mortality from visual predators such as birds). In addition, the surgically